A retrospective epidemiologic analysis of human salmonellosis in Hawaii suggests that the reported incidence is seven to eight times higher than in the rest of the United States, and discusses the reasons for this difference. Hogs and hog products are a chief reservoir and vehicle of transmission to humans.

Epidemiologic Aspects of Salmonellosis in Hawaii

K. L. Gould, M.D.; J. M. Gooch, D.V.M., M.P.H.; and G. Q. L. Ching, B.S.

Introduction

Salmonellosis is a widespread public health problem in the United States. The major vehicles of infection for humans are foods of animal origin, particularly frozen or dried egg products, dried milk, poultry, and packaged boneless meats.[1-14] However, salmonellae are transmitted widely or cause outbreaks through such diverse products as seafoods,[1] bakery goods,[11,15,16] coconut,[17,18] food supplements[19,20] cotton seed protein,[20] dried yeast[20,21] cereal powder[22] smoked fish,[23] unpasteurized whole milk,[24] water[25] and carmine dye.[26] Control is difficult due to the diversity and complexity of chains of food production and distribution.

Since 1950 Hawaii has had a reported incidence of human salmonellosis seven to eight times higher than the national incidence, as reported by the National Communicable Disease Center. This report reviews laboratory documented salmonellosis in Hawaii since 1950 with the intent of explaining this high reported incidence and presents data which suggest that incidence based on reported cases is an inadequate parameter for comparing levels of salmonellosis among states. Sources of human infection are described based on the distribution of salmonellae sterotypes from animal and human sources, contamination of foods of animal origin, distribution of human salmonellosis by season, and incidence by race.

Methods

Laboratory Procedures

Isolation and serotyping of salmonellae were performed at the Laboratory Branch of the Hawaii Deprtment of Health. All specimens were streaked on Salmonella-Shigella (SS) agar and enriched in selenite F and tetrationate-brilliant green broths. After incubation at 37°C for 24 hours. Colonies resembling salmonellae on SS agar were subcultured into tubes of Triple Sugar Iron (TSI) agar. After incubation at 37° for 24 hours, TSI cultures exhibiting reactions characteristic of salmonellae were tested for urease activity. All urease negative cultures were tested for mobility, indole production, and fermentation of dextrose, sucrose, mannitol, and salicin. Cultures showing reactions characteristic of salmonellae were typed serologically by somatic O and flagella H antisera to determine the group and specific serotype.

Epidemiologic Data

A single microbiology laboratory in the Hawaii Health Department serotypes salmonella isolates from laboratories throughout the state. The laboratory has detailed records on all cases of salmonellosis since 1950. For this study, a case of salmonellosis is defined as the first isolation of any serotype from a person in a given calendar year. If an individual yielded one serotype several times in a year, he was counted as "one case." If an individual yielded different serotypes at different times during a year, each different serotype was counted as one case. In the period 1950 through 1966 the Laboratory Branch of the Hawaii Health Department reported 5,940 cases in the entire state; 93.7 per cent of these were on the most populous island, Oahu. These laboratory documented cases are the basis of this report.

Incidence was calculated as the number of cases in a year divided by appropriate population data provided by the Office of Research, Planning, and Statistics of the Hawaii Department of Health. Data on other states was obtained from the National Communicable Disease Center.[3]

There are six major islands in Hawaii. Eighty-two per cent of Hawaii's 713,909 residents (1966 data) live on Oahu. Forty-eight per cent of Oahu residents live in the city of Honolulu. Population breakdowns by age, sex, race and census tract are available.

Frequency or prevalence of infection by a particular serotype was calculated as the total number of individuals harboring a particular serotype divided by the total number of individuals harboring salmonellae of all serotypes.

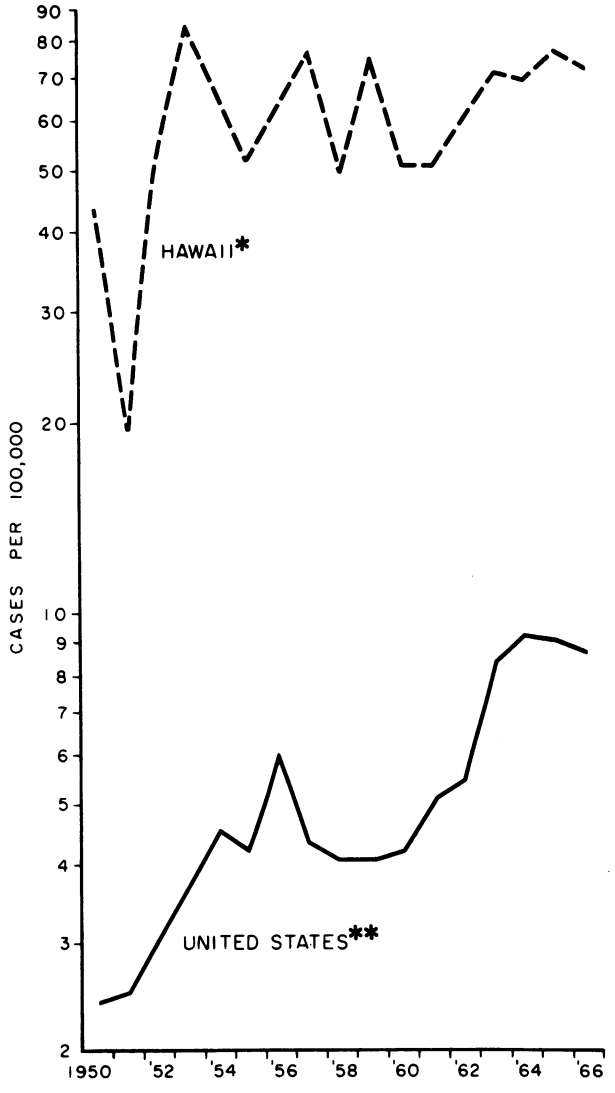
Serotypes from animal sources were obtained from four sources: a survey of animals, poultry, slaughterhouses, equipment, and asymptomatic persons on Oahu during 1960 to 1962;[27] a survey of meats and meat products of intrastate, interstate, and foreign origin marketed in Oahu in 1967;[28,29] a piggery study on Oahu in 1967 and 1968;[30] specimens from animal sources submitted by the Hawaii Department of Agriculture and the Public Health Veterinarian during the years 1960-1967. All of these studies utilized surface swabs of food products or equipment, cecal swabs of slaughtered animals, and rectal swabs of live animals.

The numbers of animals or samples of animal products yielding a given serotype were totaled. Frequency or prevalence for each serotype was calculated as the number of animals or samples yielding that serotype divided by the total number yielding salmonellae of all serotypes.

As shown in results, incidence in adults did not appear to reflect a "true level" of salmonellosis because incidence varied with interest factors and because adults often had no symptoms (their infections were diagnosed by routine surveillance). This finding made it difficult to interpret incidence by race in adults. To avoid this difficulty, age specific incidence was analyzed for each race. The age group chosen was two years old or younger since the majority of this group had symptoms (93.4 per cent as shown in results).

Race was determined as much as possible in accordance with the definitions of the U. S. Bureau of the Census.[31] Case records also included information on the race of contacts and parents of each patient. In certain respects definitions of race utilized by the U. S. Census are arbitrary and difficult to interpret, particularly for persons of mixed racial extraction. Because of this difficulty, incidence was also calculated utilizing persons of pure racial extraction. Incidence calculated for pure races were similar to incidence by race calculated from U. S. Census data. Therefore, only age-race specific incidence based on definitions and data of the U. S. Bureau of the Census are presented in this paper.

Figure 1—Incidence of Human Salmonellosis in Hawaii and the United States, 1950-1966



*LABORATORY REPORTED CASES, HAWAII DEPARTMENT OF HEALTH

**LABORATORY REPORTED CASES, NATIONAL COMMUNICABLE DISEASE CENTER, SALMONELLA SURVEILLANCE, ANNUAL SUMMARY, 1966

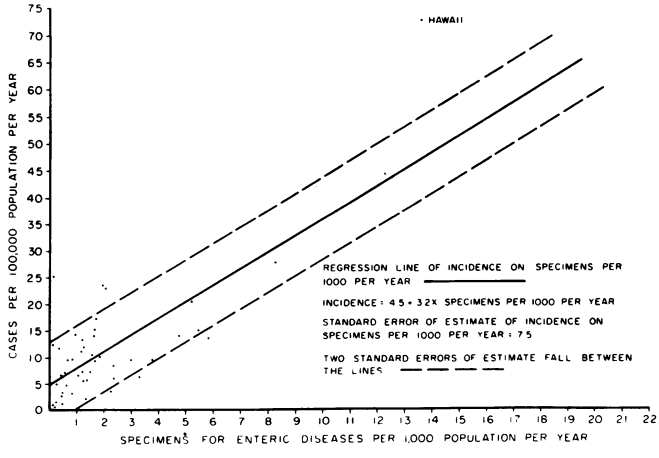
Results and Discussion

Incidence of human salmonellosis in Hawaii based on Laboratory reported cases was 70 to 80 per 100,000 per year for the period 1964-1966; this is seven to eight times higher than the reported national average.[29] Incidence in Hawaii from 1950 through 1966 rose as did national trends but at approximately seven times the national level. (Figure 1)

This high incidence may be due to factors other than more widespread infection in Hawaii. To compare Hawaii with other states, bias from various factors must be considered. Among these factors are the high level of interest by health personnel and the community, the availability of a convenient laboratory, and extensive surveillance activities. In Hawaii, large numbers of specimens are submitted for suspected enteric diseases, and there is a concomitant high reported incidence of human salmonellosis. Without such awareness, small numbers of specimens for enteric diseases would be submitted, with concomitant low incidence.

A measure of these "interest factors" is the number of specimens for enteric diseases submitted to a state laboratory per 1,000 population per year. Such data are available for 47 states including Hawaii for the years 1964, 1965, and 1966.[37] The number of specimens submitted for enteric diseases per 1,000 population per year and the incidence of salmonellosis among states. If incidence were directly proportional to the number of specimens submitted for enteric not included). A correlation coefficient between incidence of human salmonellosis and specimens per 1,000 population per year was computed as +0.75 with a standard error of 0.15 and P value of less than 0.0001. The regression line of incidence on specimens per 1,000 population was expressed by the equation; Incidence (cases per 100,000 per year) = 4.5 + 3.2 times specimens per 1,000 population per year;

Figure 2—Correlation of Incidence of Human Salmonellosis with Number of Specimens for Enteric Diseases Submitted per 1,000 Population for 47 States, 1964, 1965 and 1966



one standard error of estimate was 7.5. The graph of this equation is shown in Figure 2. In other words, incidence was directly proportional to the number of specimens for enteric disease submitted (per 1,000 population per year) in the 47 states. The statistically appropriate ratio of incidence (cases per 100,000 per year) to specimens (per 1,000 population per year) for the nation is given by the slope of the regression line, which is 3.2.

The relationship of incidence to specimens collected is also shown in Table 1. In Hawaii for the years 1964 through 1966, the number of specimens for enteric disease submitted to the state laboratory was 14.0 per 1,000 population per year, compared with a national figure of 1.5 per 1,000 per year. In Hawaii for these years incidence was 72.5 per 100,000 per year compared with a national figure of 10.4 per 100,000 per year. These figures further illustrate that incidence depends on how many specimens are submitted. These data suggest that incidence of human salmonellosis alone may not be an adequate parameter for comparing the extent of salmonellosis among states. If incidence were directly proportional to the number of specimens submitted for enteric diseases, as suggested by the above correlation, the latter factor should be considered in comparing salmonellosis experience in different states. The ratio of incidence (cases per 100,000 per year) to number of specimens submitted (per 1,000 population per year) gives a truer picture than incidence alone for such comparisons. This ratio, which we call the salmonellosis index, accounts for interest factors. For Hawaii during 1964, 1965 and 1966 this index was 5.2, compared with 3.2 (the slope of the regression line) for the nation (Table 1), suggesting that incidence of salmonellosis in Hawaii is seven times the national incidence because of extensive surveillance rather than more widespread infection.

Among states there may be variations in criteria for counting enteric disease specimens, in the completeness of reporting specimens and cases, and in the number of screening cultures examined by private laboratories. Specimens submitted to state laboratories may represent a varying per cent of the total number of cultures taken in a state. For these reasons the salmonellosis index can be approximate only and should not be interpreted in a strictly quantitative sense. In spite of these problems which would tend to reduce the correlation coefficient, the correlation between incidence and specimens submitted is fairly good for the 47 states for which information is available.

Yearly incidence of human salmonellosis in Hawaii for the years 1964-1966 was 1.9 times higher than in 1950-1952. (Table 2) To reduce the bias of interest factors, we used the above approach in comparing the two periods. In Hawaii the number of specimens for enteric diseases submitted to the laboratory was 12.3 per 1,000 population per year during 1950-1952. The same microbiology technician has been performing isolation and serotyping procedures since before 1950, using the same techniques and media. This suggests that the rising incidence in Hawaii represents a real increase and is not due to improved laboratory methods or greater interest.

Incidence on Oahu 1950-1966 was at least 4 times higher than that of the other islands combined. (Table 3) The number of specimens submitted for enteric diseases per 1,000 population per year on Oahu was only 1.5 times the figure for other islands. The salmonellosis index on Oahu was 4.6 whereas on other islands combined it was 1.4. Thus, compared to other islands, Oahu appeared to have more salmonellosis than can be accounted for by population size or interest factors.

Age specific incidence based on laboratory reports from 1950 to 1966 suggested that children were primarily affected. (Table 4) The incidence for children two years old or younger was six or seven times higher than for persons over ten. However, these figures may reflect rates of clinical disease rather than rates of infection, since 93.4 per cent of the youngest group had frank diarrhea, whereas only 54.6 per cent of the oldest group had frank diarrhea (asymptomatic patients were cultured during follow-up activities or surveys, or during febrile illnesses without diarrhea). Since young children apparently had diarrhea more often than infected adults, cultures were probably taken more frequently, with resulting higher reported incidence in the younger age group. Further data consistent with this hypothesis are also seen in Table 4, which shows the per cent of cases in each age group found by survey and follow-up activities regardless of the presence of diarrhea. If there had been no surveillance activity, incidence in the group ten years

Table 1—Incidence of Human Salmonellosis and Specimens for Enteric Diseases Submitted to State Laboratories in the Nation and Hawaii, 1964, 1965, 1966

	Nation (47 states, including Hawaii)	Hawaii
Incidence, cases per 100,000 per year	10.4	72.5
Specimens per 1,000 population per year	1.5	14.0
Salmonellosis Index	3.2*	5.2

*The slope of the regression line of incidence on specimens per 1,000 per year.

Table 2—Incidence of Human Salmonellosis and Specimens for Enteric Diseases Submitted to Hawaii State Laboratories, 1950-1952 and 1964-1966

	1950-1952	1964-1966
Incidence, cases per 100,000 per year	38.3	72.5
Specimens per 1,000 population per year	12.3	14.0
Salmonellosis Index	3.1	5.2

Table 3—Incidence of Human Salmonellosis and Specimens for Enteric Diseases on Oahu and Other Islands of Hawaii, 1950-1966

	Oahu	Other Islands
Incidence, cases per 100,000 per year	76.4	15.9
Specimens per 1,000 population per year	16.7	11.4
Salmonellosis Index	4.6	1.4

or older would be much lower and a greater proportion would have had symptoms.

Yearly trends of the ten serotypes most commonly isolated from humans in Hawaii since 1950 showed an increasing prevalence of *Salmonella weltverden, S. heidelberg, S. infantis,* and *S. manhattan.* Frequency of other serotypes was decreased, unchanged, or erratic. For 1960-1967 the ten most common serotypes from human and animal sources are listed in decreasing order of frequency in Table 5. Nine of the ten most common serotypes from humans were among the ten most common serotypes isolated from animal sources, particularly isolates from Hawaii hogs and hog products. This comparison suggests that the distribution of serotypes isolated from humans closely parallels the distribution of serotypes from animal sources in Hawaii. For humans on the mainland, prevalence of serotypes was available from the National Communicable Disease Center's Salmonella Surveillance Reports for years 1963-1967. For these years only five of the ten most common serotypes from humans in Hawaii were among the ten most common serotypes from humans on the mainland. Thus, the distribution of serotypes, from humans in Hawaii appears to be different from the distribution of serotypes from humans on the mainland or other Pacific states.

In Hawaii for 1960-1967 the average number of salmonellosis cases per month was highest in December and January and lowest in March, April and May. (Figure 3) The number of cases per month during the peak was twice that found during March-May. On the mainland the number of cases per month was greatest during September and October and was lowest during January and February (Figure 4). Seasonal distribution of salmonellosis in Hawaii generally follows the seasonal pattern for the nation, except for the high December-January levels found in Hawaii.

This seasonal distribution of salmonellosis in Hawaii would not be expected on the basis of constant subtropical climate. Production of various food products in that state such as beef, poultry, eggs, milk and feed grains, varied little with season for 1960-1967.[32] However, for these years the number of hogs slaughtered per month in December was 50 per cent higher than during the rest of the year. This peak of hog slaughter is due to seasonal festivities and just precedes the peak of human salmonellosis in January.

Limited surveys of animals, abattoirs, markets and foods of animal origin in Hawaii have indicated reservoirs of salmonellae and vehicles for transmission. (Tables 6, 7, 8, 9) These studies showed that up to 76% of hog intestines or viscera may be contaminated with this organism. Beef, poultry, eggs, and feed grains showed relatively little contamination. Galton and others[33-36] have shown that hogs at slaughter may also be infected in mainland states. In Hawaii hog stomachs and intestines are sold to markets and then to individuals and restaurants as food items without heat or chemical processing. The intestines of every hog slaughtered are sold by meat markets, even during peak

Table 4—Relation of Incidence of Salmonellosis to Age, Presence of Symptoms, and Manner of Finding Cases on Oahu, Hawaii, 1950-1966

	2 Years or Less	3-9 yr.	10-19 yr.	20 or Greater
Incidence in cases per 100,000 per year	323.3	55.4	22.3	54.7
Per cent of total cases in each age group showing diarrhea	93.4%	71.3%	55.4%	54.6%
Per cent of total cases in each age group found by Health Dept. surveillance activities	11.7%	39.9%	41.7%	46.8%
Total cases in each age group on Oahu	2066	721	323	2457

Table 5—Ten Most Common Serotypes of Salmonellae Isolated From Human and Animal Sources, Hawaii, 1960-1967

Human Sources			All Animal Sources		Hogs, Hog Products	
Salmonella serotype and rank	% of total	Among the ten most common from human and animal sources	Salmonella serotype and rank	% of total	Serotype and rank	% of total
1. typhimurium	17.6	yes	1. anatum	21.4	1. anatum	21.4
2. derby	9.7	yes	2. manhattan	15.0	2. manhattan	19.2
3. infantis	9.7	yes	3. typhimurium	12.0	3. derby	16.1
4. panama	8.5	yes	4. derby	11.8	4. infantis	13.0
5. weltverden	7.5	yes	5. infantis	11.3	5. panama	9.3
6. anatum	6.2	yes	6. bredney	6.3	6. typhimurium	6.5
7. manhattan	5.9	yes	7. panama	5.5	7. weltverden	4.0
8. heidelberg	4.8	no	8. weltverden	3.5	8. bredney	3.4
9. newport	4.6	yes	9. newport	2.5	9. tenn	1.9
10. bredney	3.2	yes	10. kentucky	2.0	10. st. paul	1.5
All other serotypes	21.6		All other serotypes	8.8	All other serotypes	3.7
Total per cent	100.0		Total per cent	100.0	Total per cent	100.0
Total number	3,488		Total number	635	Total number	323

slaughter season of December. Markets distributing hog viscera are particularly contaminated by salmonellae. (Table 7)

These hog intestines are utilized by certain ethnic groups in soups and stews. There is excellent opportunity for cross contamination of equipment and other foods before they are sold or cooked. Ethnic utilization is apparent in the incidence by race for the age group two years or younger, as seen in Table 10. The two ethnic groups which utilize these products (primarily Chinese and Filipino) have an incidence two to five times that of other ethnic groups. The racial group "all other" is a heterogenous mixture including Negro, Portugese, Puerto Rican and unknown. The numbers of cases and population in each race of this "other" category is quite small and the incidence for this group is not a reliable figure. Utilizing cases of pure or mixed racial extraction to calculate incidence and comparing age, sex, and socioeconomic characteristics of cases in each ethnic group did not alter these conclusions.

Summary

This study is a retrospective epidemiologic analysis of laboratory reported human salmonellosis in Hawaii. The results suggest: (a) reported incidence in Hawaii is seven to eight

Figure 3—Seasonal Distribution of Human Salmonellosis, Hawaii, 1960-1967

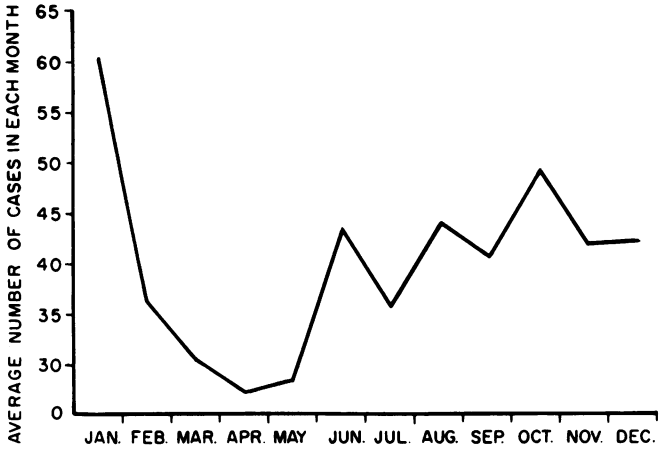


Table 6—Species Surveyed for Salmonella on Oahu, Hawaii, 1960-1962

Species	No. examined	No. positive	% positive
Hogs	288	90	31.3
Rats	62	11	17.7
Chickens	559	45	8.1
Dogs	259	12	4.6
Cows	107	0	0.0
Cats	64	0	0.0

Table 7—Equipment Surveyed for Salmonella on Oahu, Hawaii, 1960-1962

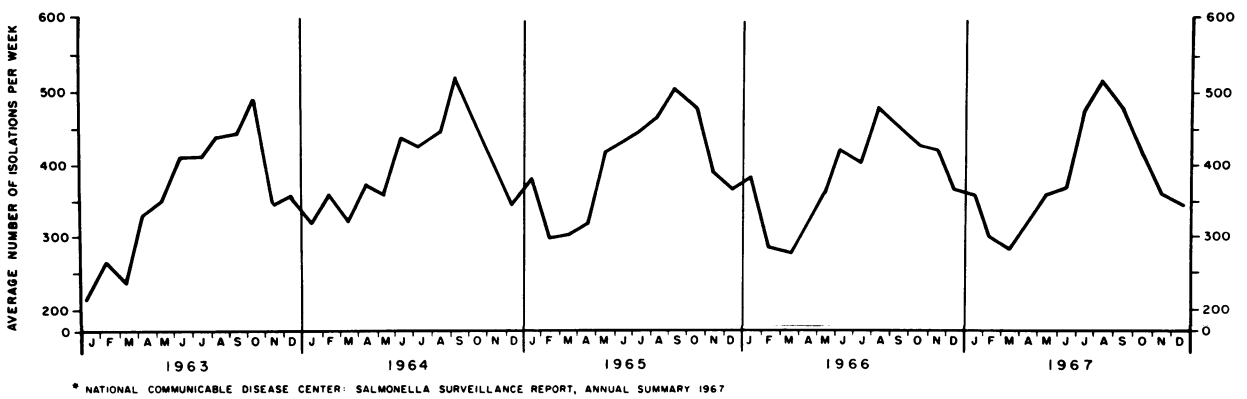
Source of equipment	No. examined	No. positive	% Positive
Poultry slaughterhouse	71	0	0.0
Hog slaughterhouse	10	3	30.0
Meat market	739	14	1.9
"open air" markets (distributors for hog intestines)	135	10	7.4
super markets	117	0	0.0
neighborhood markets	487	4	0.8

Table 8—Hog Products Surveyed for Salmonella on Oahu, Hawaii, 1960-1962

Product	No. examined	No. positive	% Positive
Hog carcass—before final wash	24	6	25.0
Hog carcass—after final wash	39	1	2.5
Hog—hearts and livers*	21	9	42.9
Hog—stomach and intestines*	18	8	44.4

*At the time of this study all internal organs of hogs were processed on the same table on which intestines were handled. As a result these organs were contaminated from naturally infected intestines.

Figure 4—Reported Human Isolations of Salmonellae United States, 1963-1967



* NATIONAL COMMUNICABLE DISEASE CENTER: SALMONELLA SURVEILLANCE REPORT, ANNUAL SUMMARY 1967

Table 9—Meat Products Surveyed for Salmonella on Oahu, Hawaii, 1967

Product	Origin	No. sampled	No.. positive	% Positive
Beef loin strips	Intrastate	50	2	4.0
	Interstate	49	0	0.0
	Foreign	50	4	8.0
Poultry-fryers	Intrastate	50	1	2.0
	Interstate	50	0	0.0
Pork-loins	Intrastate	50	0	0.0
	Interstate	50	0	0.0
Pig stomachs*	Intrastate	55	42	76.4
	Interstate	51	1	2.0
	Total	455	50	11.0

*At the time of this study stomachs of hogs were processed on the same table on which intestines were handled. As a result stomachs were contaminated from naturally infected intestines.

Table 10—Race-Specific Incidence of Human Salmonellosis in the Age Group Two Years or Younger, Hawaii, 1950-1964

Race	Number of cases	Cases per 100,000 per year
Caucasian	200	97.7
Hawaiian	118	101.5
Chinese	166	496.9
Filipino	202	358.3
Japanese	261	197.4
All others	82	392.7
Unknown*	584	

*Race could not be determined in 584, or 36.2% of the 1,613 cases in this age group, 1950-1964. The group in which race was known was similar to the group of total cases with respect to distribution by age, year of onset, month of onset, island, and serotype. Thus, the group in which race was known (i.e. 63.8% of the total) was a representative sample of the total number of cases two years old or younger.

times higher than in the nation as a whole due to more intensive surveillance and culturing for salmonellae in Hawaii than in other states; (b) the increasing incidence of human salmonellosis in Hawaii since 1950 is due to more widespread infection, not increasing surveillance or culturing for salmonellae; (c) the reported incidence in young children in Hawaii is higher than in adults in part because children had symptoms more often than adults, were more often cultured because of symptoms, and had a concomitant higher incidence than adults, many of whom were asymptomatic and cultured only during routine surveillance; (d) hogs and hog products are a primary reservoir and vehicle for transmission of salmonellae to humans in Hawaii.

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Dr. Gould is formerly Epidemic Intelligence Service Officer, National Communicable Disease Center, Health Services and Mental Health Administration, Public Health Service, U. S. Department of Health, Education, and Welfare, stationed at Hawaii Department of Health, Honlulu. He is presently Instructor in Medicine, University of Washington Hospital, Seattle, Washington. Mr. Gooch is Public Health Veterinarian, Communicable Disease Division, Hawaii Department of Health. Mr. Ching is Supervisor, Medical Microbiology Section, Laboratories Branch, Hawaii Department of Health.

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